IE1206 Embedded Electronics

Le1 → Le2 PIC-block Documentation, Seriecom Pulse sensors

Le3 → Ex1 → KC1 LAB1 *I*, *U*, *R*, *P*, serial and parallell

Pulsesensors, Menuprogram

- ***Start of programing task***

Le4 → Ex2 Kirchoffs laws Node analysis Two ports R2R AD

Le5 → Ex3 → KC2 LAB2 ***Two ports, AD, Comparator/Schmitt***

Le6 → Ex4 → Le7 → KC3 LAB3 Transients PWM

Step-up, RC-oscillator

Le8 → Ex5 → Le9 Phasor jω PWM CCP KAP/IND-sensor

Ex6 → Le10 → Le11 → KC4 LAB4 ***LC-osc, DC-motor, CCP PWM***

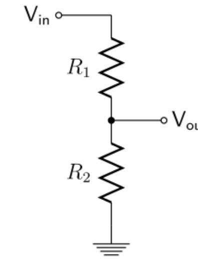
Le12 → Ex7 → Display LP-filter Trafo

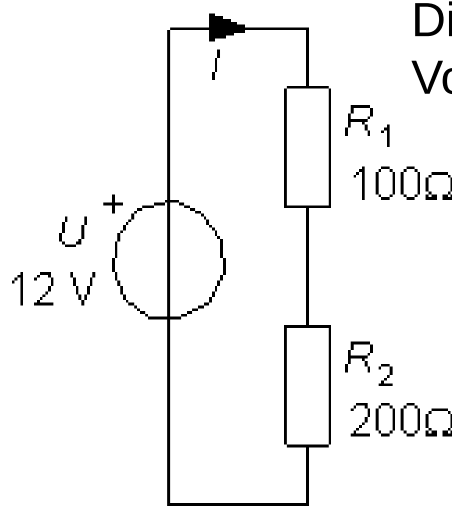
- ***Display of programing task***

Le13 → Written exam Trafo, Ethernetcontact

William Sandqvist william@kth.se

Voltage divider formula





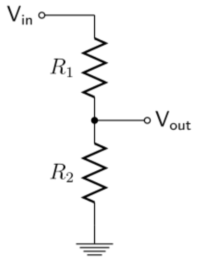
Divided Voltage | Total Voltage | Voltage division factor

$$\boxed{U_1} = \boxed{U} \times \boxed{\frac{R_1}{R_1+R_2}} = 12\,\frac{100}{100+200} = 4\text{V}$$

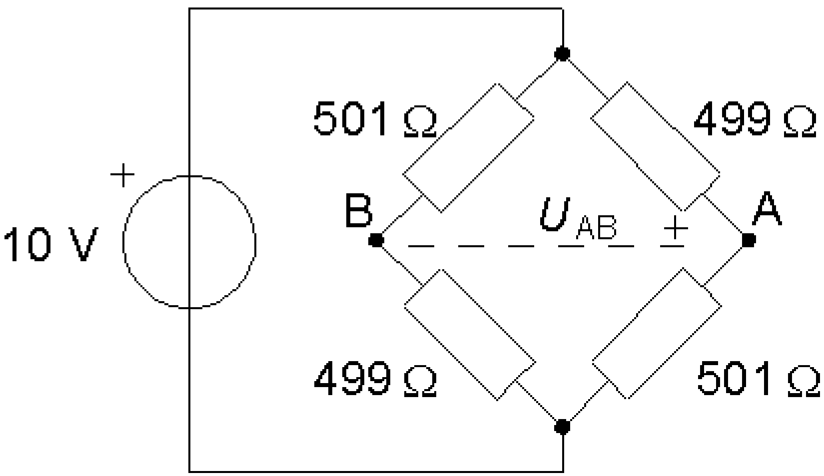
$$\boxed{U_2} = \boxed{U} \times \boxed{\frac{R_2}{R_1+R_2}} = 12\,\frac{200}{100+200} = 8\text{V}$$

According to the voltage divider formula you get a divided voltage, for example U_1 across the resistor $R_{1,}$ by multiplying the total voltage U with a voltage division factor. This voltage division factor is the resistance R_1 divided by the sum of all the resistors that are in the series connection.

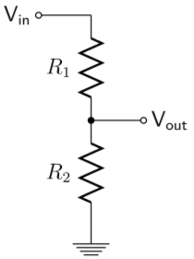
Unbalanced Wheatstone bridge



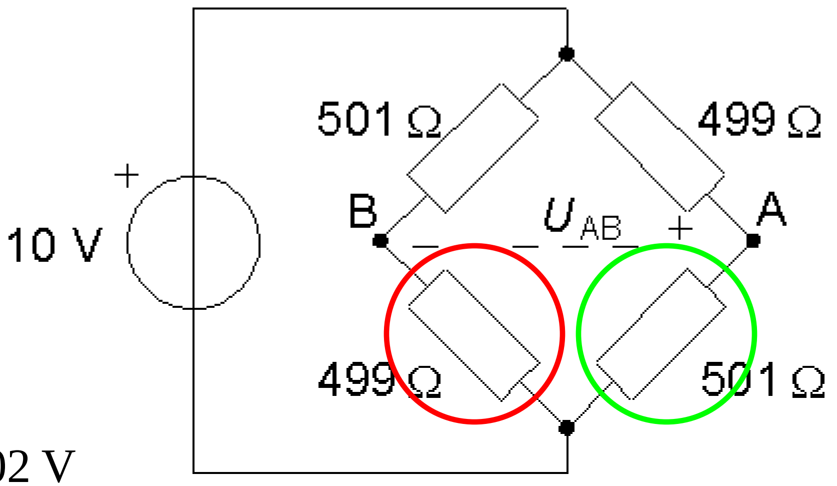
Points A and B are approximately at half the battery voltage. A is closer to "+ pole" and B is closer to "-pole." The difference U_{AB} can be measured with a sensitive millivolt meter connected between A and B.



Unbalanced Wheatstone bridge

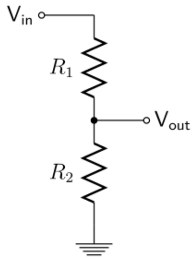


Points A and B are approximately at half the battery voltage. A is closer to "+ pole" and B is closer to "-pole." The difference U_{AB} can be measured with a sensitive millivolt meter connected between A and B.

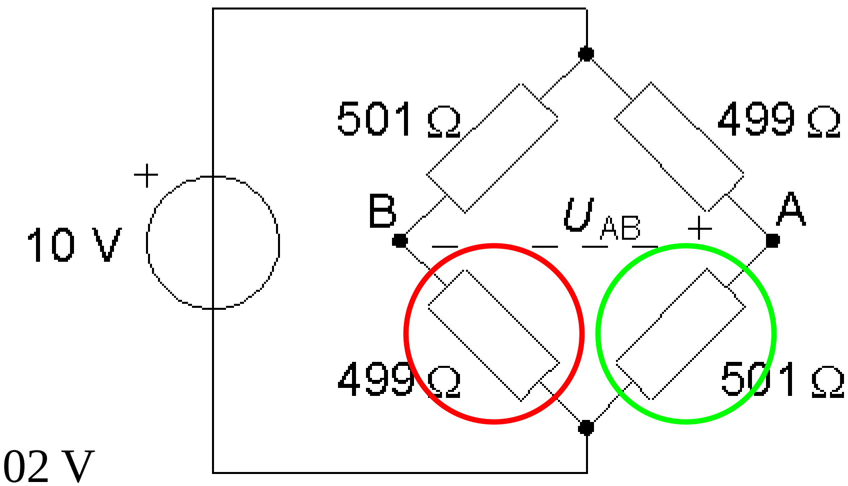


$$U_{AB} = 10\frac{501}{499+501} - 10\frac{499}{501+499} = 0{,}02 \text{ V}$$

Unbalanced Wheatstone bridge



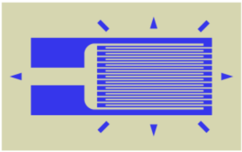
Points A and B are approximately at half the battery voltage. A is closer to "+ pole" and B is closer to "-pole." The difference U_{AB} can be measured with a sensitive millivolt meter connected between A and B.



$$U_{AB} = 10\frac{501}{499+501} - 10\frac{499}{501+499} = 0{,}02\ \text{V}$$

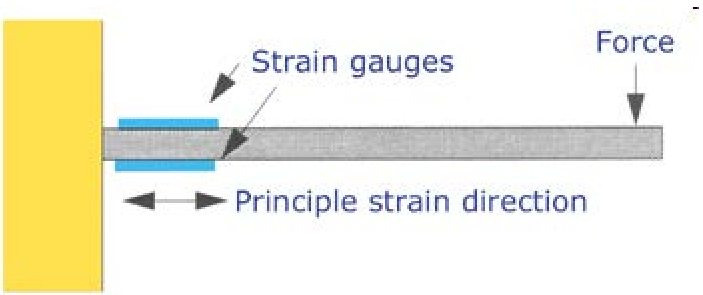
Why has the resistors values 501 and 499?

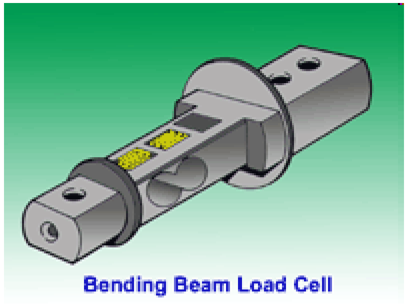
Loadcell

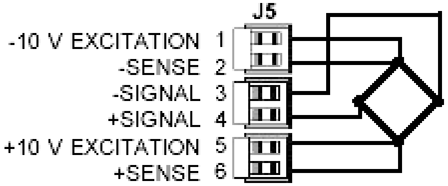


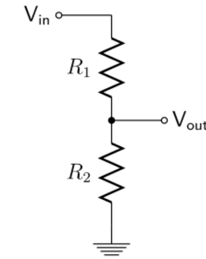
Industrial scales. Two strain gauges on the top of a beam increases from 500 to 501. Two strain gauge on the bottom of a beam decreases 500 to 499.

The gauges are connected as a Wheatstone bridge. The unbalance voltage is a direct measure on the force *F* (or if it's a scale F = mg).



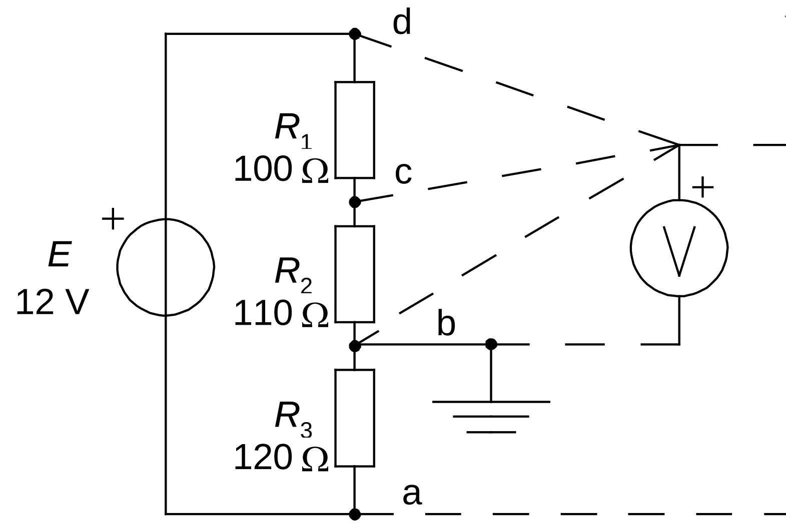






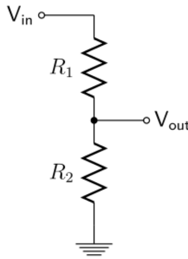
Potential (7.1)

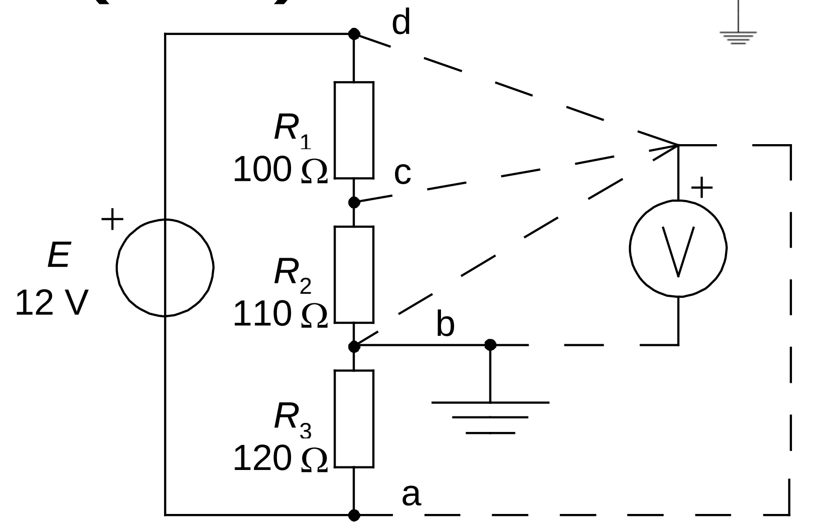
A voltage divider cosists of three resistors R_1 = 100 Ω, R_2 = 110 Ω, R_3 = 120 Ω, they are connected to a emf E = 12 V.



One measures the potential (voltage relative to ground) at various sockets on the the voltage divider.
Voltmeter negative terminal is all the time connected to the socket **b**, ground, while the positive terminal of the voltmeter in turn connects to the **a**, **b**, **c**, and **d**. What does the voltmeter show?

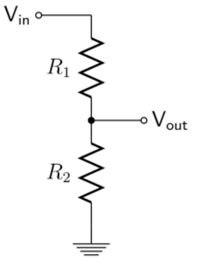
Potential (7.1)



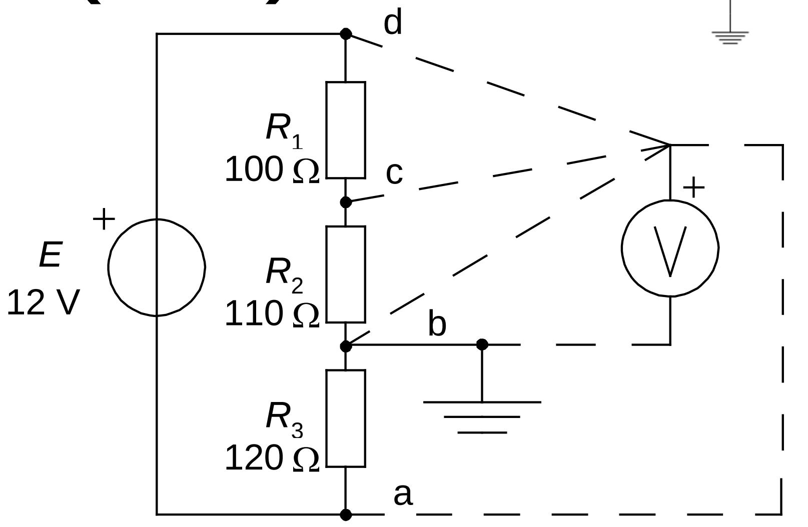


Socket	a)	b)	c)	d)
Voltmeter [V]				

Potential (7.1)

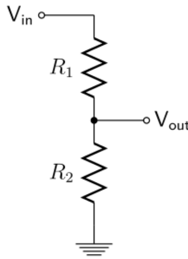


$$U_{ab} = -U_{ba} = -12\frac{120}{100+110+120} = -4{,}37$$

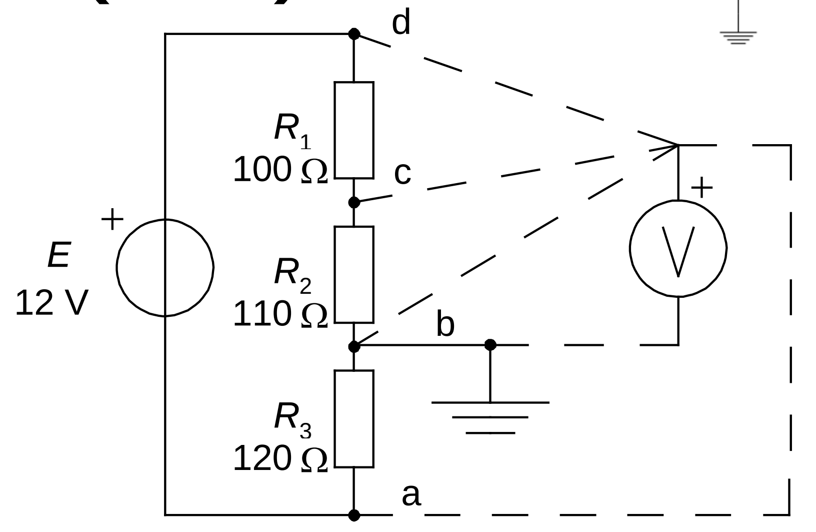


Socket	a)	b)	c)	d)
Voltmeter [V]	-4,37			

Potential (7.1)

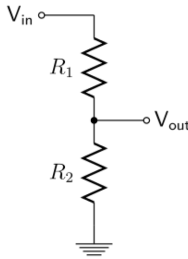


$$U_{ab} = -U_{ba} = -12\frac{120}{100+110+120} = -4{,}37$$



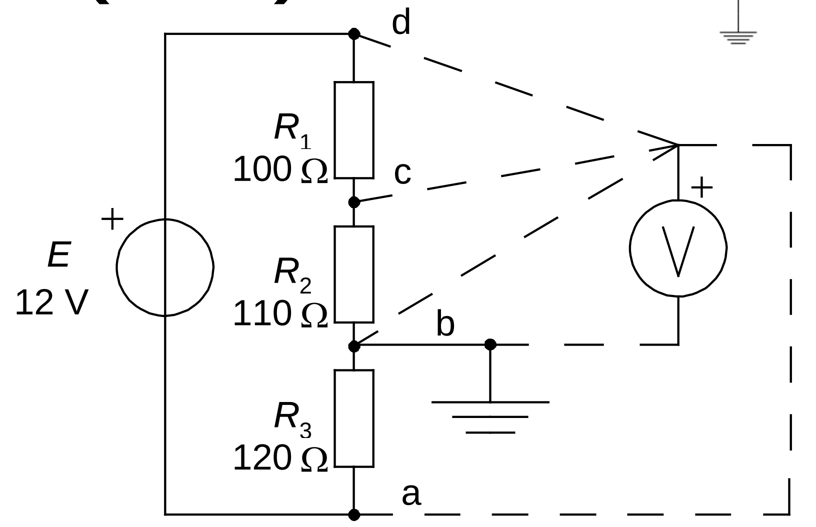
Socket	a)	b)	c)	d)
Voltmeter [V]	-4,37	0		

Potential (7.1)

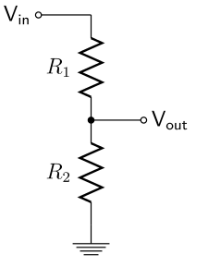


$$U_{ab} = -U_{ba} = -12\frac{120}{100+110+120} = -4{,}37$$

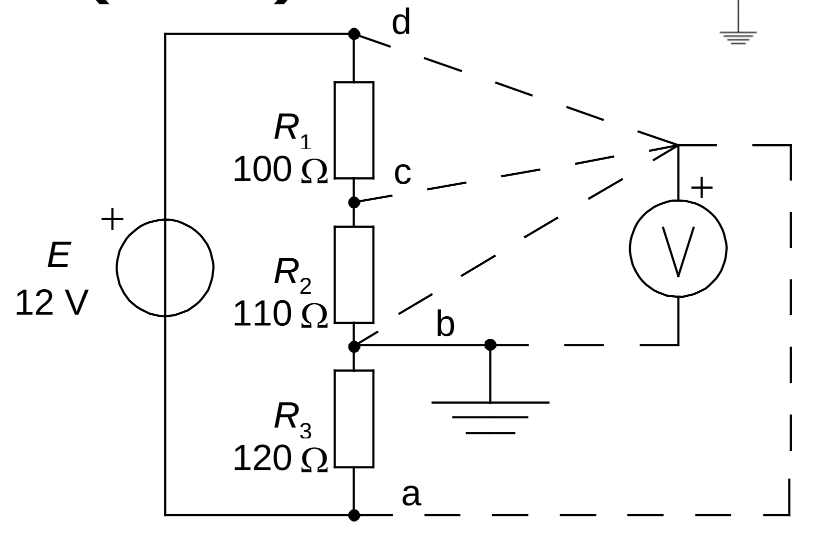
$$U_{cb} = 12\frac{110}{100+110+120} = 4$$



Socket	a)	b)	c)	d)
Voltmeter [V]	-4,37	0	4	



Potential (7.1)



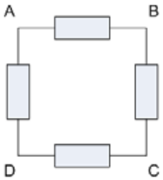
$$U_{ab} = -U_{ba} = -12\frac{120}{100+110+120} = -4,37$$

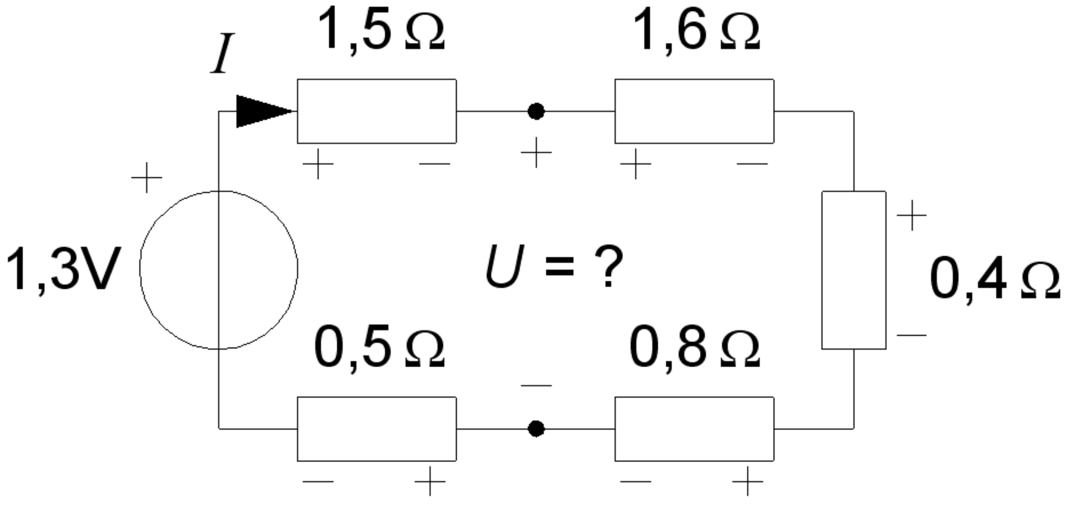
$$U_{cb} = 12\frac{110}{100+110+120} = 4$$

$$U_{db} = 12\frac{100+110}{100+110+120} = 7,64$$

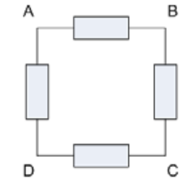
Socket	a)	b)	c)	d)
Voltmeter [V]	-4,37	0	4	7,64

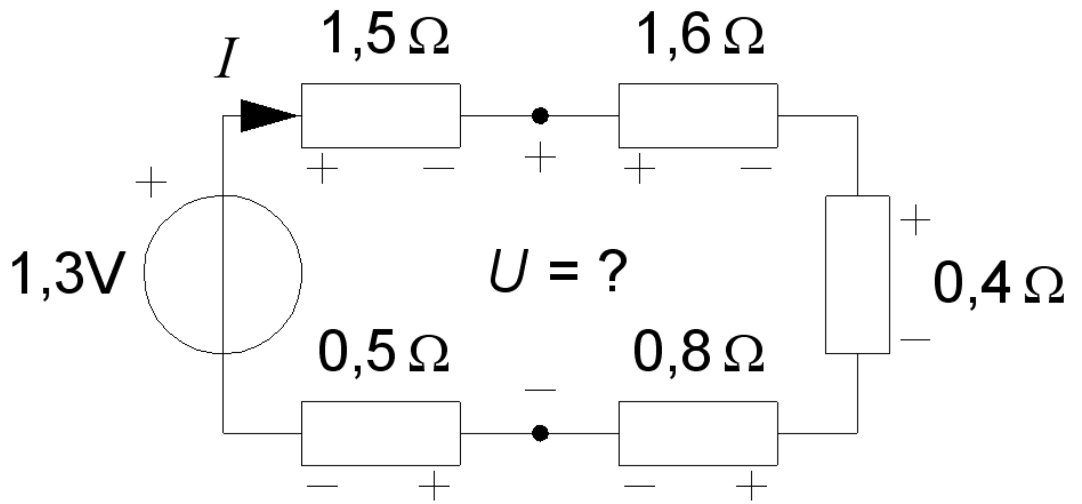
Kirchhoff's voltage law (5.3)





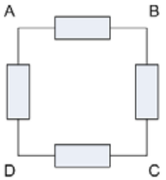
Kirchhoff's voltage law (5.3)

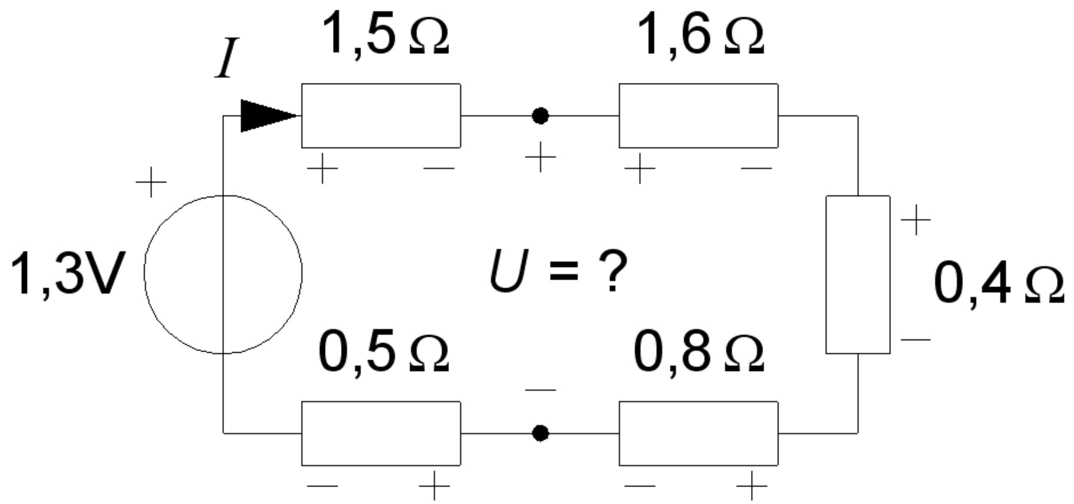




$$I = \frac{1{,}3}{1{,}5 + 1{,}6 + 0{,}4 + 0{,}8 + 0{,}5} = 0{,}27$$

Kirchhoff’s voltage law (5.3)



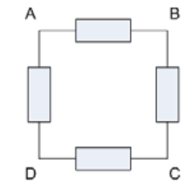


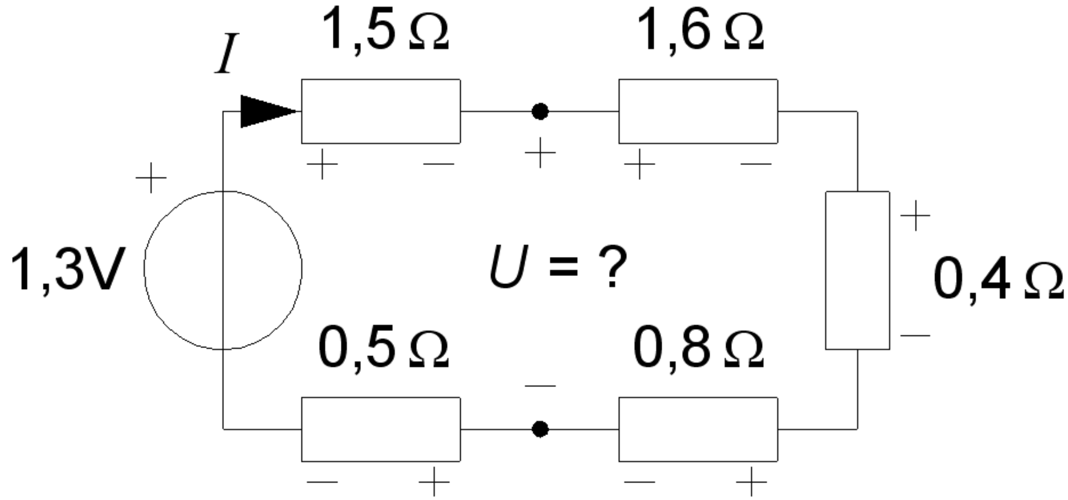
$$I = \frac{1{,}3}{1{,}5+1{,}6+0{,}4+0{,}8+0{,}5} = 0{,}27$$

$$U_{0,5} = 0{,}5 \cdot 0{,}27 = 0{,}14$$

$$U_{1,5} = 1{,}5 \cdot 0{,}27 = 0{,}41$$

Kirchhoff’s voltage law (5.3)





$$I = \frac{1{,}3}{1{,}5 + 1{,}6 + 0{,}4 + 0{,}8 + 0{,}5} = 0{,}27$$

$$U_{0,5} = 0{,}5 \cdot 0{,}27 = 0{,}14$$

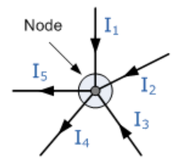
$$U_{1,5} = 1{,}5 \cdot 0{,}27 = 0{,}41$$

$$U = -\,0{,}14 + 1{,}3 - 0{,}41 = 0{,}76 \text{ V}$$

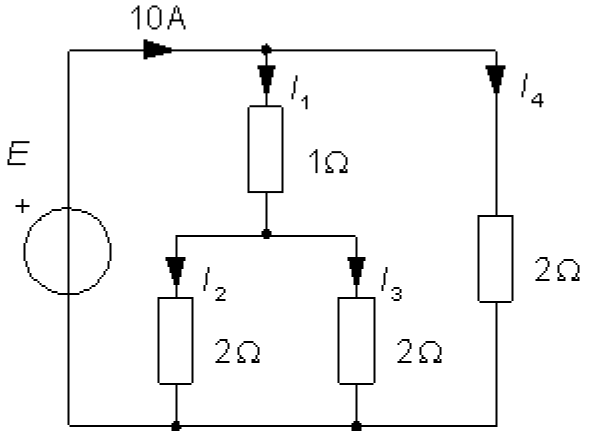
eller $U = 0{,}27 \cdot (0{,}8 + 0{,}4 + 1{,}6) = 0{,}76$ V

William Sandqvist william@kth.se

Kirchhoffs current law (5.1)



Can you guess the currents?



$I_1 =$ 5 A
$I_2 =$ 2,5 A
$I_3 =$ 2,5 A
$I_4 =$ 5 A

$I_1 + I_4 = 10$

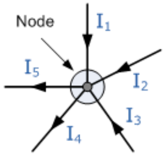
$I_1 = I_2 + I_3 \quad I_2 = I_3$

Parallel circuit, OHM's law: $I_4 \cdot 2 = I_1 \cdot (1+2//2) \Rightarrow I_4 = I_1 = 10/2 = 5$

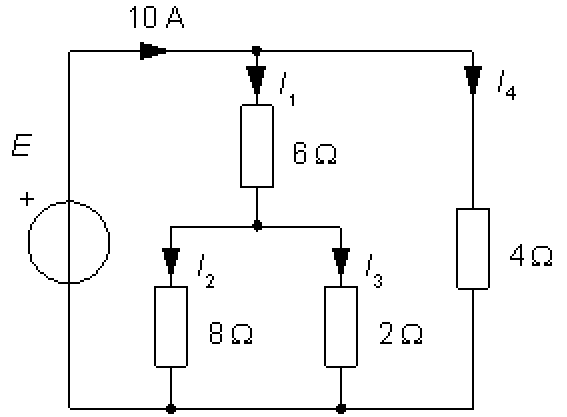
$I_1 = I_2 + I_3 \Rightarrow I_2 = I_3 = 5/2 = 2,5$

William Sandqvist william@kth.se

Kirchhoffs current law (5.2)



Now we must calculate

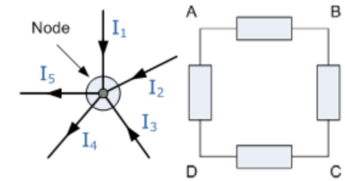


$$R_{ERS} = \frac{\left(6+\frac{8\cdot 2}{8+2}\right)\cdot 4}{\left(6+\frac{8\cdot 2}{8+2}\right)+4} = 2.62\ \Omega \qquad E = R_{ERS}\cdot I = 2{,}62\cdot 10 = 26{,}2\ \text{V}$$

$$I_4 = \frac{E}{4} = \frac{26{,}2}{4} = 6{,}55\ \text{A} \qquad I_1 = I - I_4 = 10 - 6{,}55 = 3{,}45\ \text{A}$$

$$I_2 = \frac{E - 6\cdot I_1}{8} = \frac{26{,}2 - 3{,}45\cdot 6}{8} = \frac{5{,}5}{8} = 0{,}69\ \text{A} \qquad I_3 = \frac{5{,}5}{2} = 2{,}75\ \text{A}$$

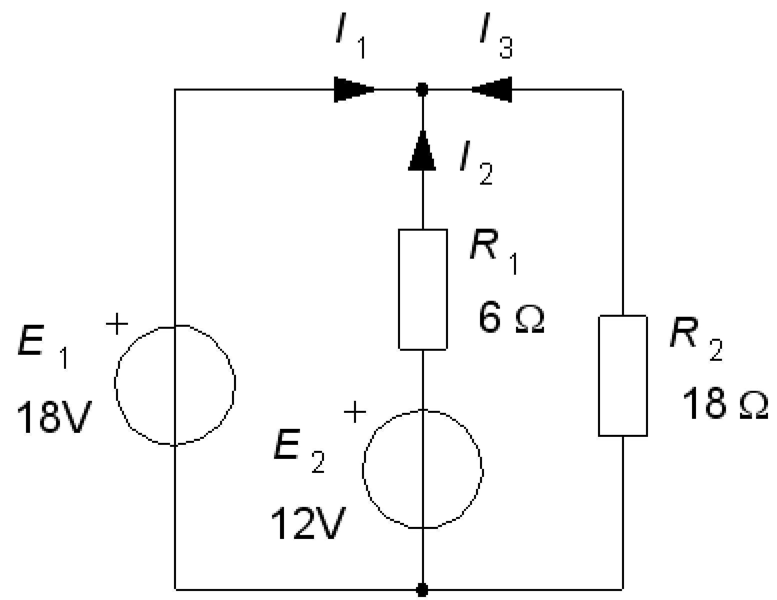
Kirchhoffs laws? (6.3)



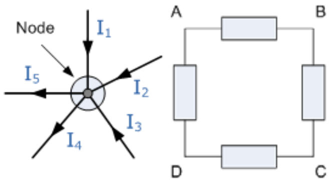
a) $U_{R2} = ?$

b) $I_2 = ?$

c) $I_1 = ?$



Kirchhoffs laws? (6.3)

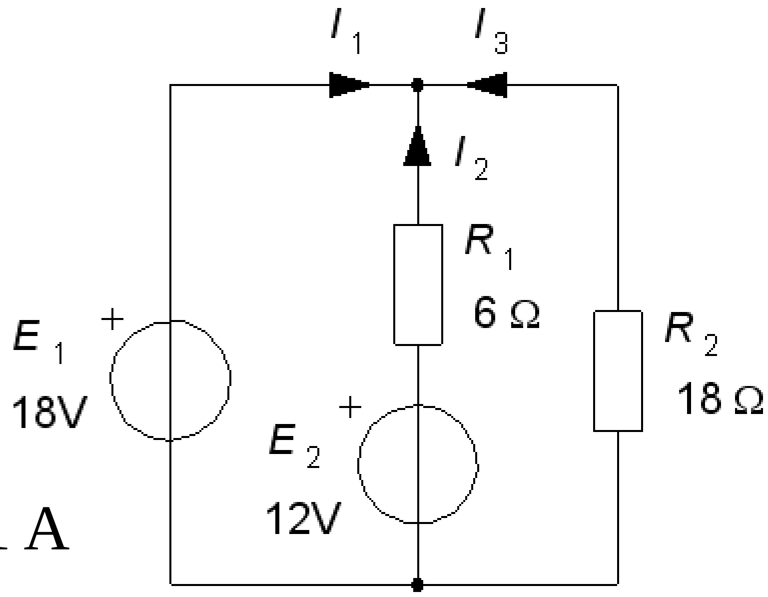


a) U_{R2} = ? = 18 V (E_1)

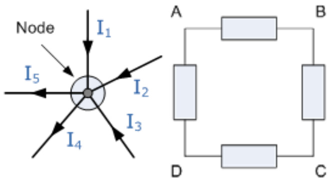
b) I_2 = ?

c) I_1 = ?

$18 + I_3 18 = 0 \quad I_3 = -18/18 = -1$ A



Kirchhoffs laws? (6.3)



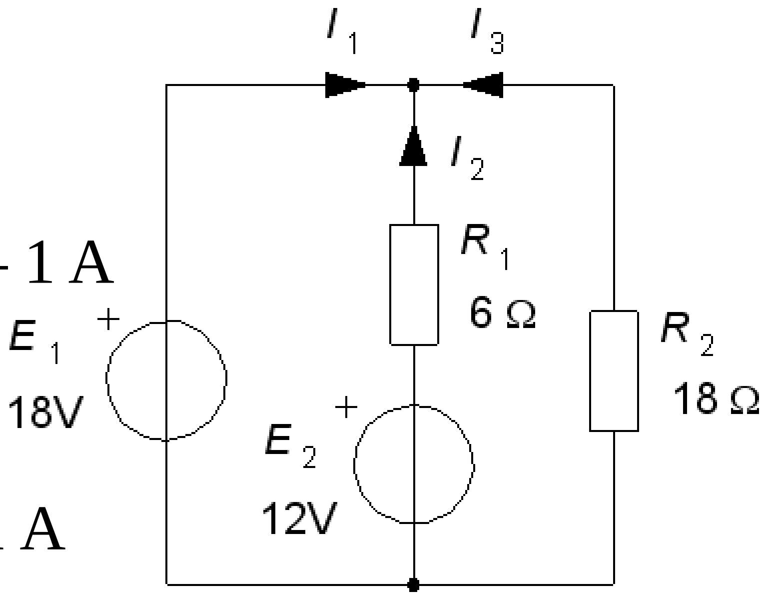
a) U_{R2} = ? $= 18\ \text{V}\ (E_1)$

b) I_2 = ? $18 + 6I_2 - 12 = 0$

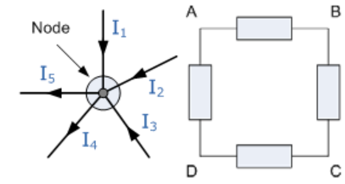
$I_2 = (12 - 18)/6 = -1\ \text{A}$

c) I_1 = ?

$18 + I_3 18 = 0 \quad I_3 = -18/18 = -1\ \text{A}$



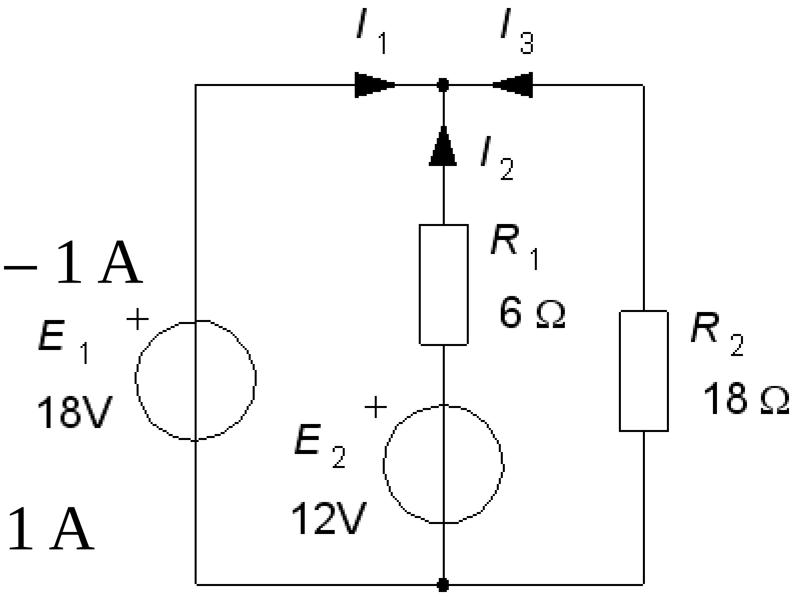
Kirchhoffs laws? (6.3)



a) U_{R2} = ? $= 18$ V (E_1)

b) I_2 = ? $18 + 6I_2 - 12 = 0$

$I_2 = (12 - 18)/6 = -1$ A



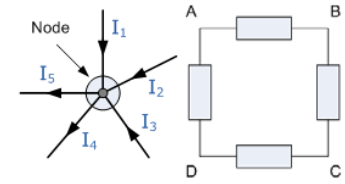
c) I_1 = ?

$18 + I_3 18 = 0 \quad I_3 = -18/18 = -1$ A

$I_1 + I_2 + I_3 = 0$

$I_1 = -I_2 - I_3 = -(-1) - (-1) = 2$ A

Kirchhoffs laws? (6.3)

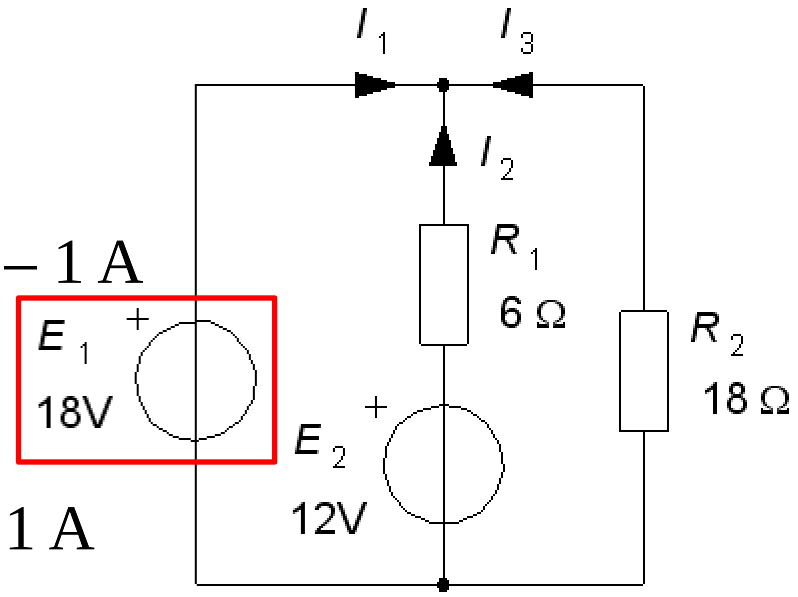


a) U_{R2} = ? $= 18$ V (E_1)

b) I_2 = ? $18 + 6I_2 - 12 = 0$

$I_2 = (12 - 18)/6 = -1$ A

c) I_1 = ?



$18 + I_3 18 = 0$ $I_3 = -18/18 = -1$ A

$I_1 + I_2 + I_3 = 0$

$I_1 = -I_2 - I_3 = -(-1) - (-1) = 2$ A

That E_1 is an ideal emf is what simplifies the calculations!

Or with node analysis (7.3)

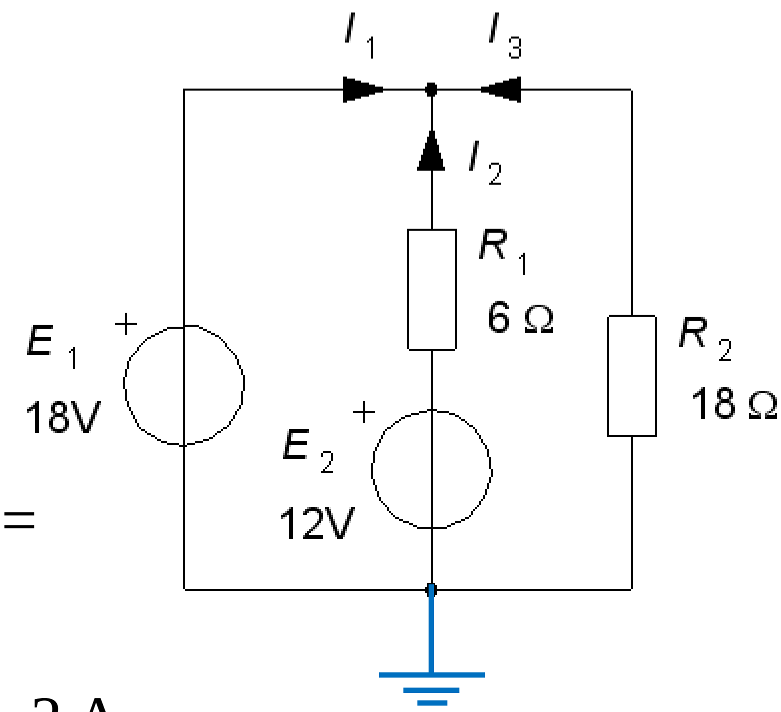
$I_1 + I_2 + I_3 = 0 \quad I_1 = – I_2 – I_3$

$E_1 = 18$ V

$I_3 = – (E_1 – 0)/R_2 = – 18/18$
$= – 1$ A

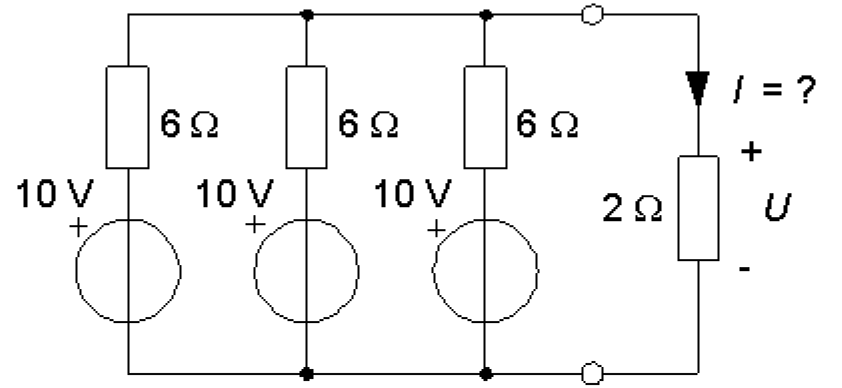
$I_2 = – (E_1 – E_2)/R_1 = – (18 – 12)/6 =$
$= – 1$A

$I_1 = – I_2 – I_3 = – (– 1) – (– 1) = 2$ A

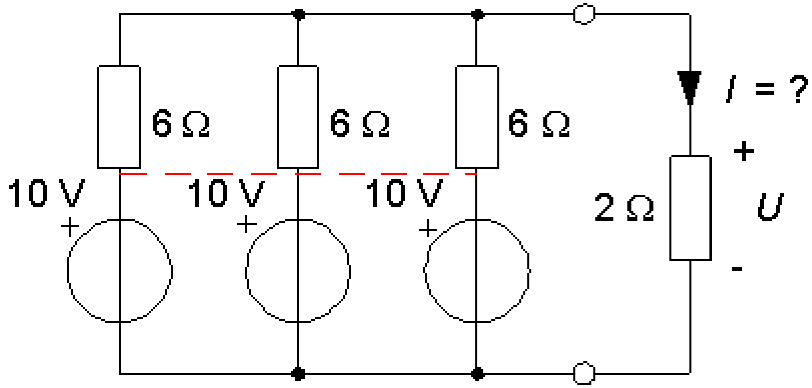


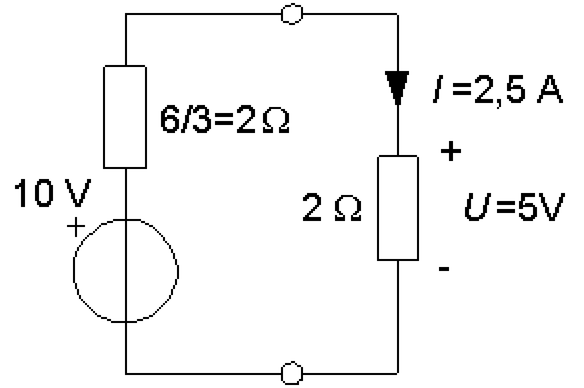
Batteries in parallel (4.4)

Three similar batteries E = 10 V and the internal resistance 6 Ω are parallel-connected to deliver current to a resistor with resistance 2 Ω.
a) How much will current I and terminal voltage U be?

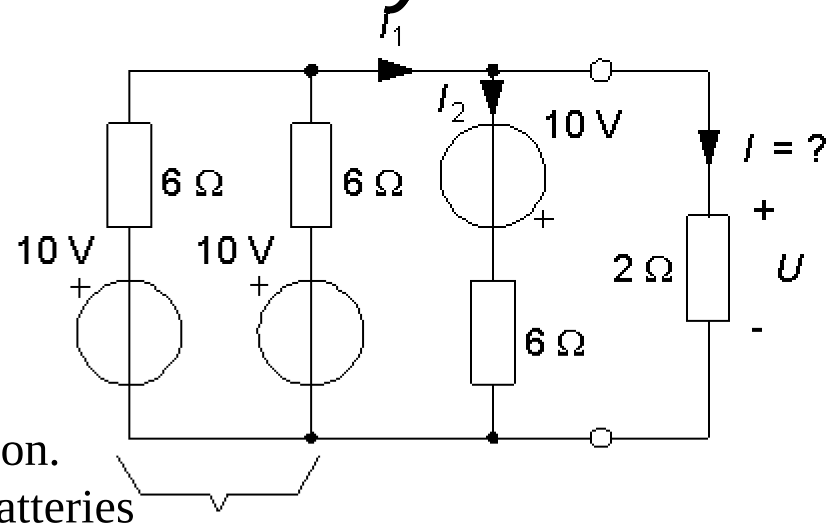


The three internal resistances 6Ω have common voltage in both ends, and is thereby effectively paralleled. $R_I = 6/3 = 2\Omega$. I = 2,5 A och U = 5V.



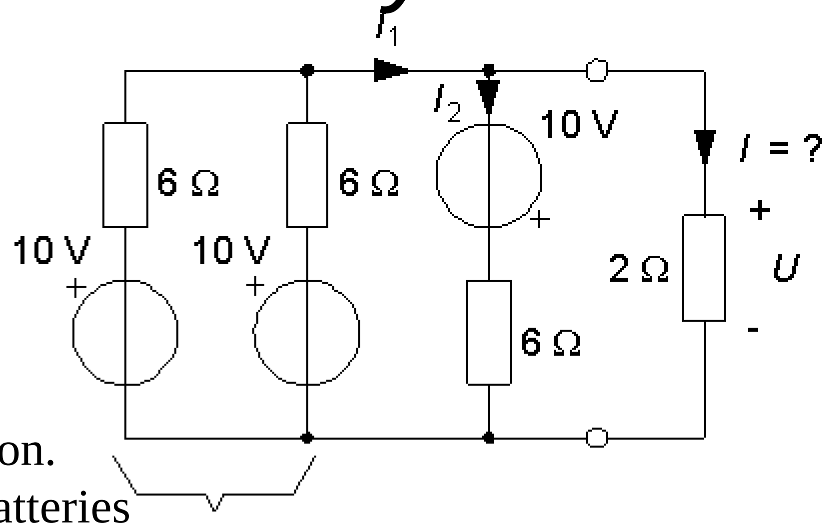


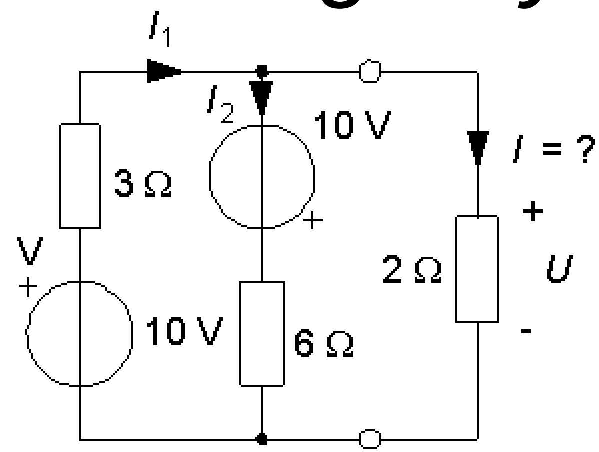
One battery inserted the wrong way!



Suggestion.
Merge batteries

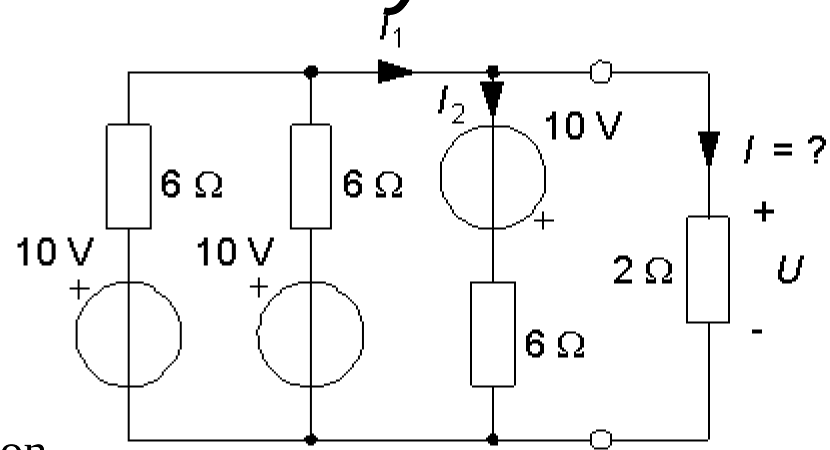
One battery inserted the wrong way!

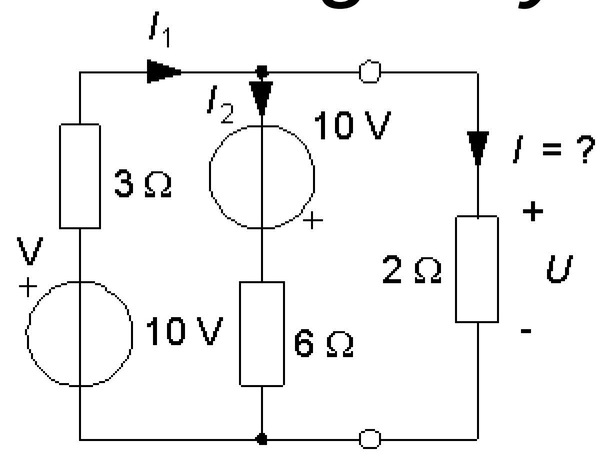




Suggestion.
Merge batteries

One battery inserted the wrong way!

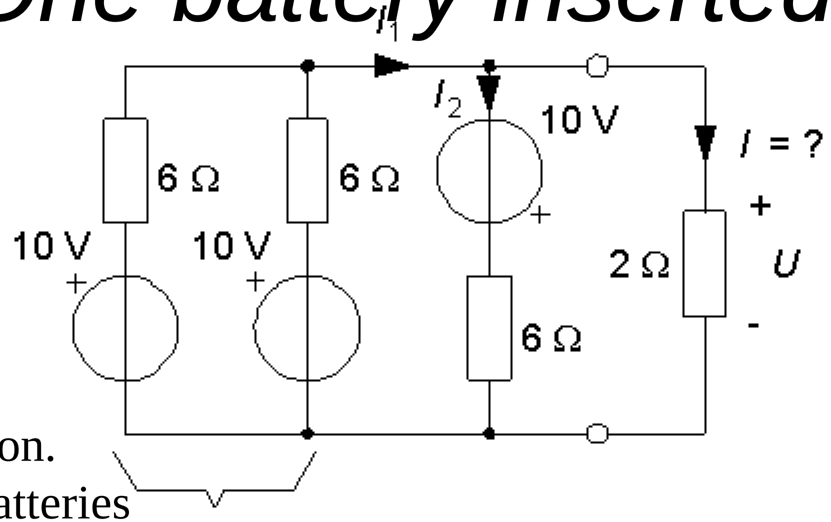


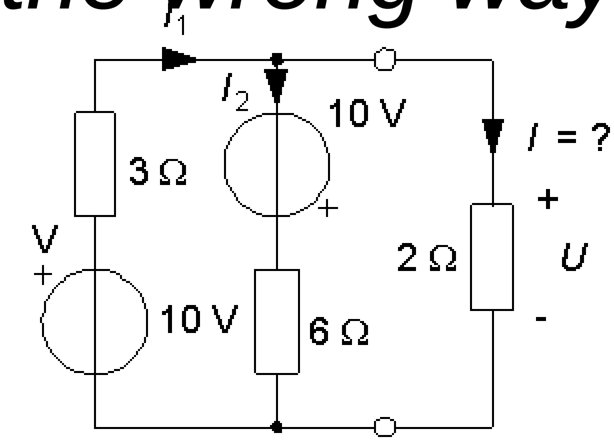


Suggestion.
Merge batteries

This is now a more complicated circuit that requires Kirchhoff's laws to be solved ...

One battery inserted the wrong way!





Suggestion.
Merge batteries

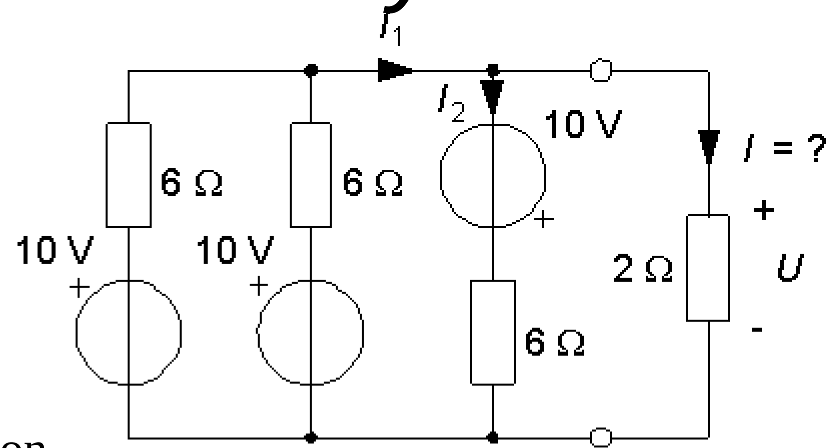
$$I_1 - I_2 - I = 0$$

$$10 - 3I_1 + 10 - 6I_2 = 0 \quad \Leftrightarrow \quad -3I_1 - 6I_2 + 0I = -20$$

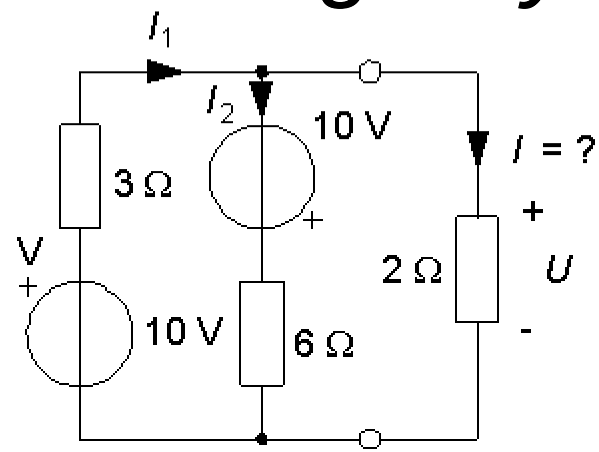
$$6I_2 - 10 - 2I = 0 \quad \Leftrightarrow \quad 0I_1 + 6I_2 - 2I = 10$$

$$\begin{pmatrix} 1 & -1 & -1 \\ -3 & -6 & 0 \\ 0 & 6 & -2 \end{pmatrix} \cdot \begin{pmatrix} I_1 \\ I_2 \\ I \end{pmatrix} = \begin{pmatrix} 0 \\ -20 \\ 10 \end{pmatrix}$$

One battery inserted the wrong way!



Suggestion.
Merge batteries



$$I_1 - I_2 - I = 0$$

$$10 - 3I_1 + 10 - 6I_2 = 0 \quad \Leftrightarrow \quad -3I_1 - 6I_2 + 0I = -20$$

$$6I_2 - 10 - 2I = 0 \quad \Leftrightarrow \quad 0I_1 + 6I_2 - 2I = 10$$

$$\begin{pmatrix} 1 & -1 & -1 \\ -3 & -6 & 0 \\ 0 & 6 & -2 \end{pmatrix} \cdot \begin{pmatrix} I_1 \\ I_2 \\ I \end{pmatrix} = \begin{pmatrix} 0 \\ -20 \\ 10 \end{pmatrix}$$

$I_1 = 2{,}78$ A
$I_2 = 1{,}94$ A
$I = 0{,}83$ A

$$U = I \cdot 2 = 0{,}83 \cdot 2 = \boxed{1{,}67 \text{ V}}$$